with on the voyage, so that the recording of results was much interfered with. It will be noticed that the figures bearing on the efficiency of the *Tartar's* boilers are not given in the table. The reason is that the coefficient based on the recorded data comes out so high that the boilers could hardly have been evaporating all the feed water pumped into them. In ordinary cases we should naturally attribute this to priming; but the power developed was so small that we hesitate to apply this solution in the present case. On the other hand, the phenomenon of excessive cylinder condensation would be induced by working a big engine at low power. We have not, however, sufficient data to enable anything positive to be advanced in this connection. We understand that in ordinary working the boilers show no sign of excessive priming, and the steam space is said to be ample. The *Meteor*, the first vessel experimented upon, is 261 feet long, 32·1 feet wide, and 19·3 feet deep. Her trial displacement was 2090 tons. The engines are of the triple compound type, with three cranks at equal angles.

It will be evident that we have not space to give details of the trials as set forth by Prof. Kennedy, and any fairly intelligible abstract is difficult to make. The paper itself is merely a record of facts—a most admirably arranged record we may say in passing—and each fact is so interdependent on others, that it is difficult to make a selection. We will, however, briefly state in the form of a table a few of the leading features and final results, referring those of our readers most interested in the subject to the report itself. We include the *Meteor*, as her record is necessary to make the matter complete.

	Name of vessel.			
	Meteor.	*Fusi Yama.*	*Colchester.*	*Tartar.*
Boiler pressure above atmosphere in pounds per square inch...	145·2	56·84	80·5	143·6
Vacuum in condenser below atmosphere in pounds per square inch... ...	12·17	12·48	12·49	12·9
Revolutions per minute	71·78	55·59	{86·0 87·1}	70·0
Total mean indicated horse-power	199·4	371·3	{1022·5 957·2}	1087·4
Coal burnt per square foot grate per hour	19·25	18·98	26·1	11·93
,, ,, ,, total heating surface per hour	0·602	0·437	0·987	0·367
,, ,, 1 horse-power per hour	2·01	2·66	2·90	1·77
Carbon value of coal	0·878	0·878	0·913	1·031
Feed water per square foot total heating surface per hour in pounds ...	4·49	3·48	7·39	4·13
,, ,, pound of coal	7·46	7·96	7·49	11·23
,, from and at 212° F.	8·21	8·87	8·53	13·06
,, per indicated horse-power per hour	14·98	21·17	21·73	19·83
Calorific value of 1 pound of coal as used in thermal units	12,770	12,760	13,280	14,995
Percentage of calorific value of fuel taken up by feed water	62·0	67·2	62·0	—
,, ,, ,, ,, carried away by furnace gases	21·9	23·5	28·0	22·1
,, ,, ,, ,, lost by imperfect combustion	3·6	0·0	1·3	0·0
,, ,, ,, ,, expended in evaporating moisture in coal	1·2	0·9	0·4	0·0
,, ,, ,, ,, unaccounted for	11·3	8·4	8·3	—
Efficiency of boiler per cent.	62·0	67·2	62	—
,, ,, engine	16·1	11·2	10·7	11·5
,, ,, ,, and boiler combined	10·0	7·6	6·6	9·7

A discussion followed the reading of the paper, the most interesting feature of which was a description, by Mr. Willans, of a device he had used for investigating the effect of condensed steam in an engine cylinder. For this and other points in connection with the trials we must refer our readers to the Transactions of the Institution.

THE SCIENTIFIC INVESTIGATIONS OF THE FISHERY BOARD FOR SCOTLAND.[1]

WHATEVER may be wanting to Scotchmen in the way of Home Rule, they have no cause to complain of a want of Home Rule in their fisheries. The Fishery Board for Scotland is a complete and independent body, exercising complete jurisdiction over all the Scottish coasts, provided with an ample staff, and in receipt of a considerable amount of Government money. We learn from the introduction to the present Report that the scientific staff consists of three trained naturalists and an assistant naturalist, and besides these there is a Committee of eminent scientific men, including representatives from all the Scottish Universities. Finally, the Board has a steamer, the *Garland*, specially devoted to scientific investigations, and is able to make use of the fishery cruisers for the same purpose.

Under these favourable circumstances, and especially in virtue of the powers granted by the Sea Fisheries (Scotland) Amendment Act, 1885, the Scotch Fishery Board has exceptional opportunities for making extensive and continuous scientific investigations. The investigations for 1888 are embodied in the Report which is here dealt with. The Report is divided into three Sections. Section A is largely devoted to the experimental trawling of the *Garland* in the areas closed against beam-trawling, and to a number of statistical tables drawn up for the purpose of comparison with those experiments. This experimental trawling requires some explanation. The Act above-mentioned empowers the Scotch Fishery Board, under stated circumstances, to make by-laws for restricting or prohibiting, either entirely or partially, any method of fishing for sea fish within any specified area in any part of the sea adjoining Scotland, and within the exclusive fishery limits of the British Islands.

In accordance with the Act, by-laws were framed, prohibiting beam-trawling in districts which may roughly be described as the Firth of Forth, St. Andrew's Bay, and the Firth of Tay, and part of the sea off the coast of Aberdeenshire and Kincardineshire. This by-law came into force on April 5, 1886. Since that date the *Garland* has trawled periodically over certain definite stations within the prohibited areas, and the catches have been carefully tabulated, both as regards size and quantity. The object of the experiment is, of course, to study the effect of an enforced period of rest on the piscine fauna of the inclosed and adjacent areas, and to obtain information under the following heads:—(1) Whether the cessation of beam-trawling would cause any marked increase in (*a*) the number, (*b*) the size of trawl-fish within the closed areas. (2) Whether the closure would affect the catches of line-fishermen working in those areas. (3) Whether the closure would affect the catches of trawlers and other fishermen in adjacent areas. No fault can be found with the method of investigation, which is the only possible one under the circumstances; but, as might be expected, the results are influenced by a number of secondary causes which obscure the effect of prohibiting beam-trawling in the places mentioned. This may easily be seen by reference to the published accounts of the experiments. It was found in 1887, a year after the closure, that the average take of fish per "shot" was much greater than in the previous year in the closed areas, and that the increase was chiefly in flat fish, though also in round fish. At the same time, there was an increase in the take of all classes of fish in the free waters outside, but in general the increase in this case was in round fish, rather than in flat fish. So far, then, the experiment promised to show an immediate and most beneficial result. In 1888, however, the take of fish was very much diminished. The average number of fish of all kinds captured in the Firth of Forth per "shot" amounted to 211. In 1887 the corresponding average was 351, and in 1886, 251. There was also a considerable reduction in the average take in offshore waters, but the reduction was less than that in the closed area. Moreover, the proportional decrease of flat fish was greater than that of round fish in the closed waters, and this was more marked in the offshore waters. In St. Andrew's Bay there was, similarly, a great diminution of all kinds of fish, especially of flat fish; but outside, in the free sea, there was an increase in the flat fish and a great decrease of round fish. These negative and partly contradictory results were, without doubt, due to the exceptionally stormy weather in 1888. It shows, however, the great difficulty and complication attending fishery investigations. Nothing could seem to be more obvious than that, if trawling were prohibited in a certain area, less fish would be caught, and that their numbers would increase. The first results of the trawling experiments go to show that this is by no means necessarily the case, but that there are causes more powerful than beam-trawling which affect the numbers of fish in any season.

---

[1] "Seventh Annual Report of the Fishery Board for Scotland, being for the Year 1888." Part III., Scientific Investigations. Presented to both Houses of Parliament in pursuance of Act 45 and 46 Vict., cap. 78. (Edinburgh, 1889.)

There are also statistics showing the relative amounts of fish caught by line in restricted and unrestricted areas—that is to say, areas where beam-trawling is prohibited and where it is permitted. These statistics show an increase in the weight of fish caught by line has taken place in 1888, in both areas, but that it is proportionally larger in the unrestricted than in the restricted areas. The increase is not due to a larger number of boats and men engaged in fishing, for these have actually decreased. The statistics of line-fishing are certainly curiously contradictory to those of beam-trawling, for whereas, in 1888, the latter mode of fishing showed a decrease of flat fish in closed areas, the line-fishing showed an increase of flat fish.

It is really impossible to draw any conclusions from statistics extending over so few years. After ten years of work we shall be in a better position to judge the result of the experiment of closing certain inshore waters against trawlers. So far, it must be confessed that no case whatever has been made out against them, and the line fishermen seem to be quite as efficient in depopulating a district. From the way in which the summaries of the statistics are written, the Fishery Board may be suspected of an unconscious leaning towards the interests of the line-fishermen.

No fewer than 129 pages are devoted to the statistical tables referred to.

A very interesting Report is given in Section B (biological investigations) by Prof. Ewart on the spawning of British marine food-fishes. Space forbids a detailed criticism of this Report, but it is definite and satisfactory, and shows that, contrary to the common belief, the majority of British food-fishes do not come inshore to spawn, but at the spawning season they congregate in shoals in deeper waters. This Report is followed by a paper on the food of fishes, by Mr. Ramsay Smith. The greater part of the observations and records necessary for this work were carried out by Mr. Thomas Scott, who is a veritable giant in practical work at sea. The paper on the pelagic fauna of the Bay of St. Andrew's, by Prof. McIntosh, may be considered as complementary to Mr. Ramsay Smith's paper, since the pelagic organisms are considered from the point of view of food for adult and larval fish. Prof. McIntosh's paper, giving a record of all the pelagic organisms observed throughout the year, is a thorough and important contribution to our knowledge of the subject, and has a high practical value, especially that part of it relating to fish ova and larvæ. At the same time, it may be questioned whether the subject of fish food is not dragged in a little too much. Is it perfectly ingenuous to give a series of beautifully-coloured drawings of the metamorphoses of Actinotrocha, and to label them "Pelagic fish food"?

The descriptions of, and suggestions about, the mussel and clam beds are of obvious practical interest, and Dr. Edington's paper on the Saprolegnia of the salmon disease gives promise of a wide extension of our knowledge of a difficult subject.

The Report concludes with a careful record of physical observations made in the North Sea. The value of the physical work of the Board would be much enhanced if arrangements could be made for taking daily observations at definite stations around the Scotch coast. Such observing stations have been established by the United States Fish Commission and by the German Commission for the Scientific Investigation of German Seas, and have been fruitful of results.

The Fishery Board, it may be noticed, is only engaged in one *experiment*—that of closing certain areas against beam-trawling. The remainder of the work is in the preliminary stage of *inquiry*. In the earlier stages of fishery investigation, a large amount of biological and physical inquiry into the natural conditions of the sea is absolutely necessary, as a guide for future experiments upon marine organisms. To those who do not consider the matter attentively, these investigations may seem useless and superfluous, but they are not. It must be observed, however, that these inquiries are not an end in themselves, as in philosophical biology, but must be undertaken solely with the view of applying the experience gained to future attempts to solve the fishery problem. For example, an inquiry into the food of the different species of fishes of a district need only be made once; it is sufficient for practical purposes to know what they do generally eat, without inquiring what they may eat in exceptional circumstances. An inquiry into the relations of pelagic organisms is most useful as a guide to the life-conditions and food of fish larva and certain adult fish, but a great deal of strictly scientific work on this subject is useless; the morphology and phylogeny of each pelagic organism has not the slightest bearing on fishery questions.

The statement of the fishery question is perfectly simple. Given a continuous decrease in a number of valuable fish, due to over-fishing, how may the diminution be checked, and a continuous future supply be insured? The answer to the question is very difficult. Life in the sea is beyond control, and, to a large extent, beyond observation, for the trawl and dredge give a very insufficient idea of the conditions of marine life. There is not so close an analogy between agriculture and fisheries, as is sometimes implied in language. The sea cannot be parcelled out into inclosures; it cannot be cultivated with different kinds of crops at will; its fishes cannot be kept in confinement and protected from their enemies and the weather, nor can they be fed at regular periods as live stock are. It is misleading to talk of "reaping a harvest that is never sown," when the power of sowing *and caring for the crop* is out of reach. The ultimate aim of all scientific investigations in fishery matters must be to find out what circumstances are in human power to control, and to show how that control may best be exercised.

The first and obvious subjects for control are the fishermen themselves. If they are the cause of the depopulation of the seas, such a check may be put upon their proceedings as to obviate the evil. This may be done in one of two ways: by prohibiting fishing altogether in certain specified areas, as has been partially done by the Scotch Fishery Board, so as to afford centres from which fish may spread into the surrounding seas, or by the establishment of close seasons for different species of fish. Both methods are attended with great difficulties, which have been discussed over and over again. They may be summed up as hardship to the fishermen, and the impossibility of preventing the destruction of one species of fish whilst another is being fished for. To establish a close season which would prevent any breeding-fish being caught, would be to prohibit all fishing for three parts of the year. Secondly, the ova of breeding-fish may be artificially fertilized, the fry hatched out and turned out in great numbers to restock the waters that have been depopulated. This method is said to have been attended with success, and demands a further trial; but it must not be supposed that this process in any way resembles the rearing of domestic animals on land, or even the culture of fresh-water fish. The fry, once turned out, are lost sight of, are exposed to the attacks of numerous enemies, and are beyond all further human care. Thirdly, fish might be protected by the wholesale destruction of their natural enemies other than man, just as game is protected by the destruction of stoats, carrion-crows, and other vermin. No doubt a general massacre of cormorants, gannets, and dog-fish would make a great difference to the annual destruction of fish on our coasts, but in the case of the birds, such a course would meet with great opposition; and in the case of dog-fishes, extermination, or even an appreciable reduction in number, would be nearly impossible. Lastly, attempts may be made at culture *sensu stricto*. Young fish may be caught by the ordinary methods, and kept in suitably constructed fattening-ponds until they are of saleable size; or, to carry the process a step further, the larvæ reared in hatcheries may be turned into similar ponds and brought to maturity. These operations have been conducted with success in more places than one, but the only places where marine fish-culture forms an industry of any importance is in the Adriatic, where there are large inclosures known as *valli*, in which young fry, caught in the open sea, are inclosed and brought to a marketable condition. The possibility of cultivating mussels and oysters in the like manner is too well known to require further mention, and it is quite possible that it may be found practicable to apply the system of culture to lobsters.

These are the practical questions to which fishery officers will have to turn their attention. That a preliminary scientific training is necessary is obvious, for the art of culture requires the most exact knowledge possible of the animals under cultivation, and success will in each case depend on the extent to which the necessities of the organism are studied and supplied. But abstract scientific study must give way to practice; as soon as a man allows the problems of morphology and phylogeny to distract his attention, he will become less careful of his practical experiments, and they will end in disappointment. The Scotch Fishery Board has made an excellent beginning in its trawling experiments; in a short time it may be hoped that its staff will be engaged in numerous other experiments on the protection and production of fishes, crustacea, and mollusks, to which many of the observations published in the Seventh Report are but the preliminary.

G. C. B.

THE FIXATION OF FREE NITROGEN.[1]

In a paper communicated to the Royal Society in 1887-88 (Phil. Trans., 1889), the authors discussed the history and present position of the question of the sources of the nitrogen of vegetation. The earlier results obtained at Rothamsted, as well as those of Boussingault, under conditions in which the action both of electricity and of microbes was excluded, led the authors to conclude that the higher chlorophyllous plants have not the power of taking up elementary nitrogen by means of their leaves, or otherwise. The conclusions arrived at were, that atmospheric nitrogen is not a source of nitrogen in the case of gramineous, cruciferous, chenopodiaceous, or solaneous crops, but with regard to the *Leguminosæ* it was admitted that there was not sufficient evidence to account for the whole of the nitrogen taken up. Of the recent researches bearing on the subject, those of Hellriegel and Wilfarth, first published in 1886, were considered the most striking and conclusive.

In 1883, Hellriegel grew plants of various families in washed sand containing the necessary ash constituents but no nitrogen; in one series nothing further was given, whilst to others varying known amounts of sodium nitrate were added. The gramineous and some other plants of the first series were all limited in growth by the amount of nitrogen contained in the seed, and in the other series the growth was largely proportional to the amount of nitrogen which was applied. On the other hand, whilst most of the peas of the series to which no nitrogen was added failed after a short time, some would develop luxuriantly; and it was found that the roots of the plants of limited growth were free from nodules, and that there was abundant nodule formation on the roots of the well-developed plants. These results led Hellriegel to make further experiments, the results of which showed that leguminous plants will not develop to any extent in sterilized sand free from nitrogen; whilst in the case of peas, vetches, and some other *Papilionaceæ*, the addition of a small quantity of soil extract containing an immaterial amount of nitrogen, causes the plants to grow luxuriantly. A soil extract, prepared from an ordinary soil, which produces such striking results with the plants just mentioned has no effect with lupins. The same result is, however, readily obtained with lupins by the application of a soil extract from a sandy soil in which lupins have been growing. With clover less definite results were obtained for some time, but more recently it has been observed that whilst the extracts from other soils produce little or no effect on clover, an extract from a root-crop soil brought about a considerable nitrogen fixation; but the result was less marked than with the other leguminous plants. In all cases the nitrogen assimilation was accompanied by nodule formation on the roots. Sterilized soil extracts were entirely without effect.

As stated in a postscript to the paper in the Phil. Trans. already referred to, a preliminary series of pot experiments on similar lines to Hellriegel's was commenced at Rothamsted in 1888. The plants selected were peas, blue lupins, and yellow lupins. They were grown in washed sand containing a small amount (0·0027 per cent.) of nitrogen and the necessary ash constituents; whilst for comparison all the plants were grown in a rich garden soil, and the lupins in a special lupin soil as well. As more normal and satisfactory growth was obtained with peas, only the results relating to these will be discussed here. The lupins, which are admittedly difficult to manage under the artificial conditions which must, more or less, prevail in experiments of this kind, gave no very definite indications in the first year's experiments, although, in 1889, the most striking of the results were those obtained with yellow lupins. Of the peas grown in sand, No. 1 had nothing further added, whilst to Nos. 2 and 3 an extract from the garden soil was added. All the peas germinated and grew well, but about five or six weeks after sowing, the plants of the pots seeded with soil organisms began to acquire a darker colour than those of the pot which was not so seeded, and from this time the plants gained both in leaf surface, and in number of leaflets, and maintained a brighter green colour. At the conclusion of the experiments it was found that the roots of the plants in the unseeded pot had many nodules; the roots of the plants of the seeded pots had many more and much larger nodules than those of the unseeded pot. That these had nodules at all is to be attributed to the impurity and non-sterilization of the sand. The root, too, was much more distributed through the whole of the sand which was seeded than through the sand which was not seeded. The roots of the plants grown in garden soil were very much developed, but showed comparatively few nodules, which were, moreover, smaller than those of the other pots. Owing to the lateness of the season none of the plants flowered.

With regard to the above ground growth at the end of the experiment, there was more vegetable substance produced in the pots seeded with soil organisms than in the unseeded pot; and this increased growth was without doubt connected with the development of the root nodules and their contents. But the greatest gain was in the total nitrogen. In fact, whilst the amount of dry produce in the seeded pots was less than one-fifth more than that of the unseeded pot, there was about twice as much nitrogen in the above ground growth of the seeded, as in that of the unseeded pot. In the case of the garden soil there was more growth, more dry substance, and more nitrogen than in any of the others. In all three pots with sand, the amount of nitrogen in the produce, and in the sand, at the end of the experiment was far greater than that of the seed sown, and the sand, at the commencement. In each case the amount of nitrogen in the sand remained practically unchanged, the gain, therefore, being in the plants. The same may be said of the garden soil, but with some reserve, owing to the great difficulty, to say the least, of detecting slight changes in the amount of nitrogen in a large bulk of rich soil. There is, at least, no evidence to show that either the sand or the garden soil have taken up nitrogen on their own account, independently of the plant.

In order to show clearly that the gain of nitrogen is far beyond the limits of experimental error, it will be well to give some numerical results showing the actual amounts which had to be dealt with. Leaving out of account the difference in the amount of nitrogen of the seeds sown in each pot—the exact amounts are recorded in the paper—and the slight difference in the initial and final amounts of nitrogen in the sand, the results will be as follows:—In the 9 pounds of sand which each pot contained there was nearly 0·1 gram of nitrogen. The three seeds sown in each pot contained nearly 0·03 gram of nitrogen. At the conclusion of the experiment the vegetable produce contained: pot 1, 0·28; pot 2, 0·54; pot 3, 0·44 gram of nitrogen; which, after deducting the nitrogen of the seed sown, corresponds with a gain of 0·25, 0·51, and 0·41 gram of nitrogen.

The experiments in the second season, 1889, included the following leguminous plants: peas, red clover, vetches, blue lupins, yellow lupins, and lucerne. The sand used this time was a coarse, white sand which was well washed and also sufficiently, if not absolutely, sterilized by heating for some days at nearly 100° C. The necessary ash constituents, mixed with an equal weight of calcium carbonate, were added to each pot. There were four pots to each series. No. 1 contained the prepared sand with nothing further added. Nos. 2 and 3 the same sand to which a soil extract was added—prepared from a good garden

---

[1] "New Experiments on the Question of the Fixation of Free Nitrogen (Preliminary Notice)," by Sir J. B. Lawes, Bart., LL.D., F.R.S., and Prof. J. H. Gilbert, LL.D., F.R.S. (Proc. Roy. Soc., xlvii. 85).